WORLD-CLASS OUTSTANDING INTERNATIONAL

PROGRAM | EXHIBITION | NETWORKING

CAPACITY IMPROVEMENT OF A LARGE, TWO STAGE DIAPHRAGM COMPRESSOR

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42nd Turbomachinery
29th Pump SYMPOSIA

GEORGE R. BROWN CONVENTION CENTER
9.30 – 10.3.2013

Discussion Topics

1. Background & Compressor Details
2. Testing at Original Equipment Manufacturer (OEM) Facility
3. Initial Modifications
4. Gas Cavity Modifications
5. Summary
6. Conclusions

1a. Background

- Two stage diaphragm compressor is used to pressurize a process gas stream.
- As delivered, compressor produced less than 75% of the required flow rate at the specified suction and discharge conditions.
- **Improvement Goal: Increase capacity to deliver minimum required flow to the process.**
- An improvement effort was initiated. This presentation covers the improvements made to the compressor which resulted in a capacity increase to 98% of the design flow rate.
- The OEM was integral to this process and provided the engineering and shop time to implement the improvements.

1b. Compressor Details

- Two stage, hydraulically actuated diaphragm compressor.
- Single acting horizontal opposed design.
- 50 horsepower, belt drive @ 385 RPM.
- Discharge pressure up to 450 PSIG, 400 PSIG typical.
- Suction pressure up to 30 PSIG, 10 PSIG typical.

1c. Compressor Operation

- Reciprocating piston displaces hydraulic fluid behind diaphragm set.
- Metallic diaphragms displace gas in the “gas cavity” on the opposite side.
- Hydraulic “limiter” or “overpump valve” regulates peak hydraulic pressure and vents excess oil on each stroke of the compressor near top dead center.
- Compensating pump replenishes oil on each stroke near bottom dead center.

1d. Compressor Characteristics

1) Suction valve open. Limiter & discharge valve closed.

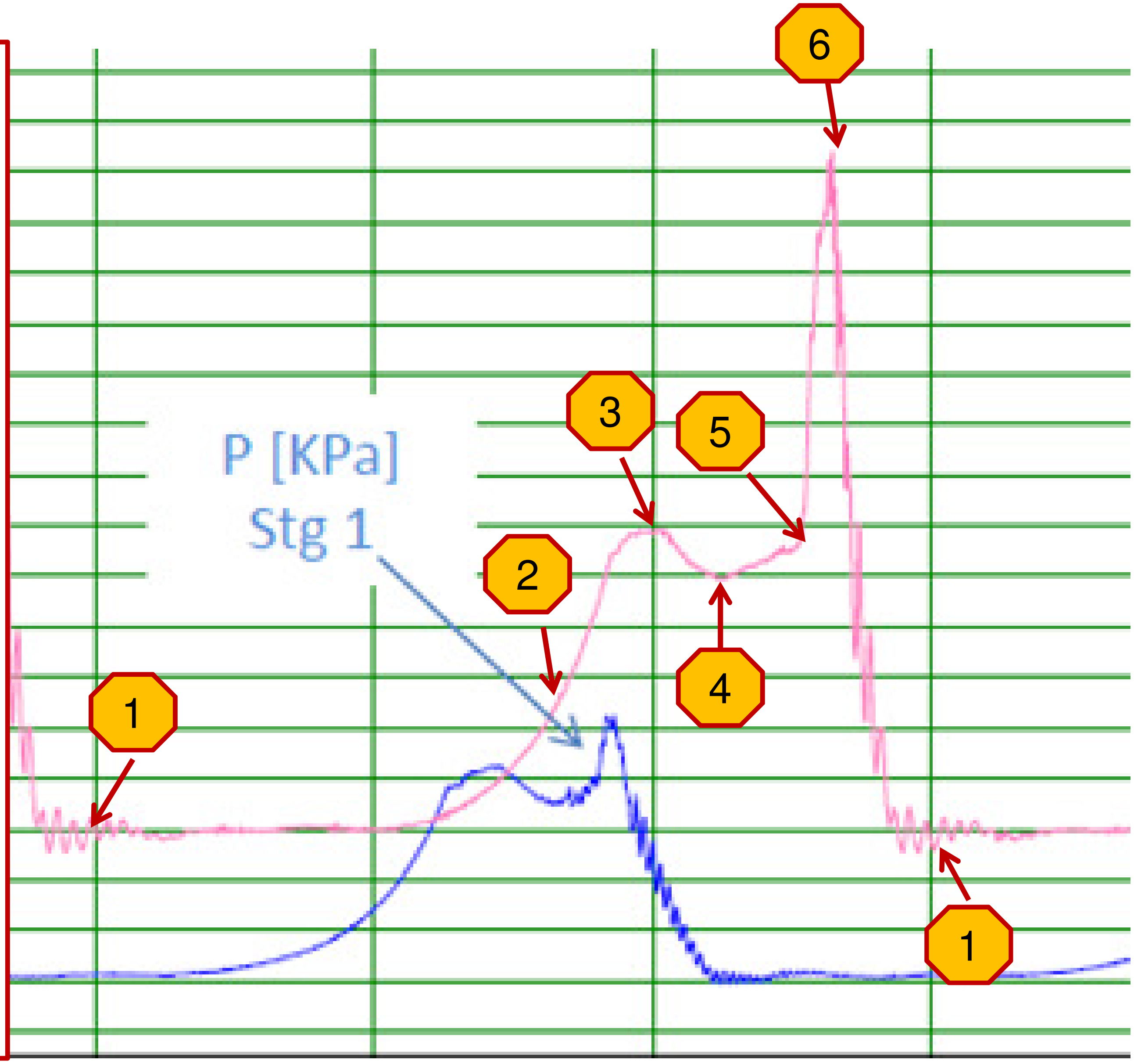
2) Compression. Limiter, suction and discharge valves closed.

3) Discharge valve open. Limiter & suction valve closed.

4) Discharge. Pressure decreases due to:
a) Piston moves slower as it approaches top dead center.
b) Flow characteristics of the discharge valve.

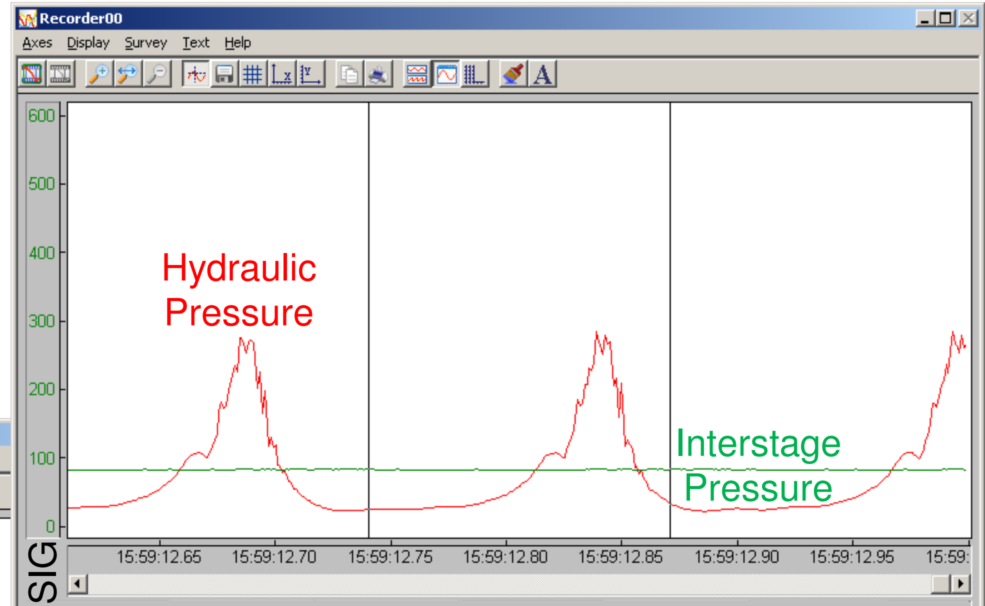
5) Diaphragm contacts the gas cavity plate. Limiter valve opens. Discharge valve still open.

6) Maximum hydraulic pressure achieved. Limiter valve closed, discharge valve closed.

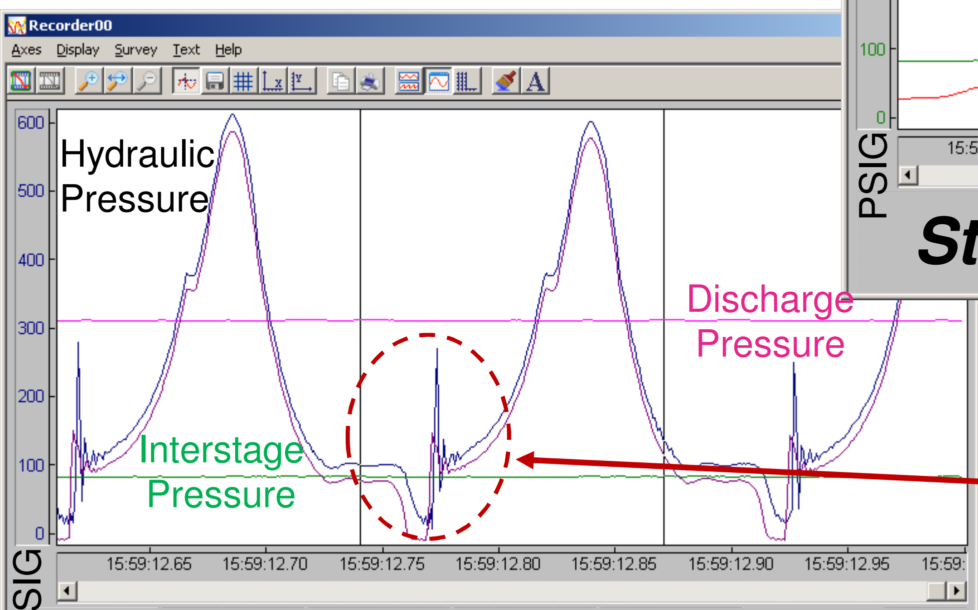


2a. Original Testing @ OEM

Original Equipment
Suction: 10 PSIG
Discharge: 310 PSIG



Stage 1 Hydraulic Pressure



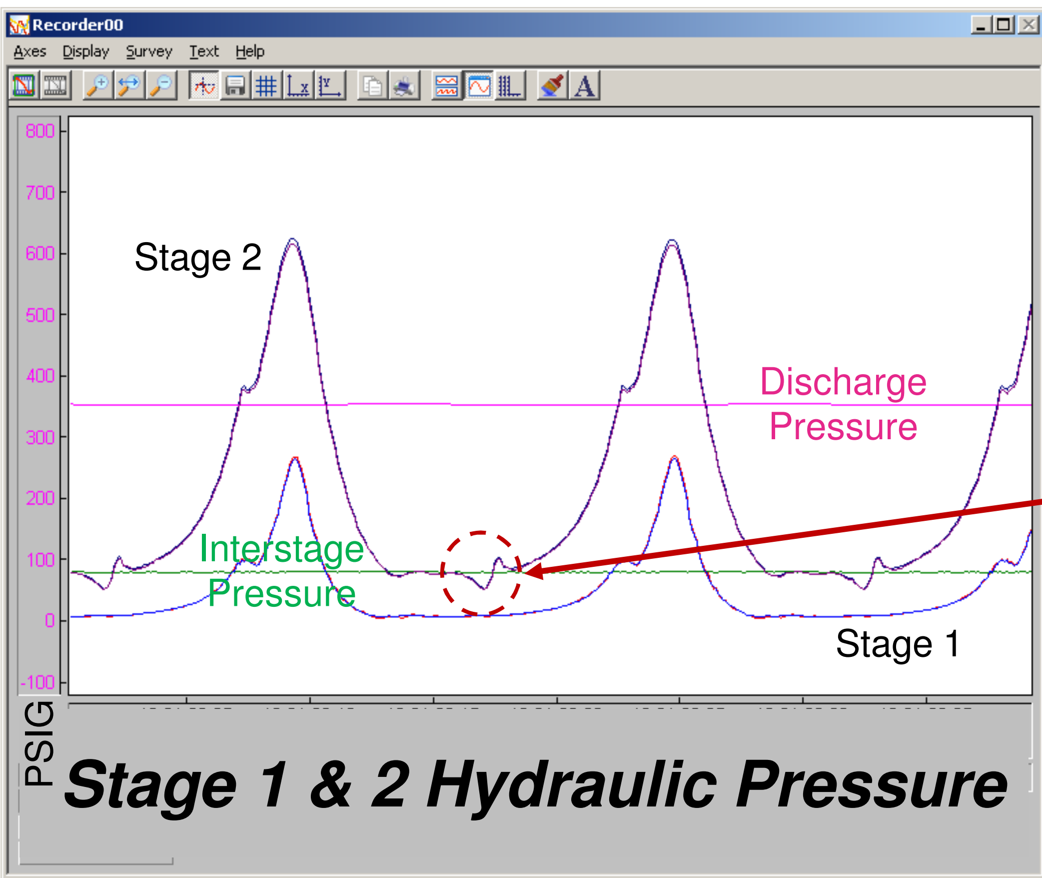
Stage 2 Hydraulic Pressure

Hydraulic Cavitation

2b. Original Testing @ OEM

Original Equipment
Suction: 10 PSIG
Discharge: 350 PSIG

Increased hydraulic pressure on stage 2 to eliminate hydraulic cavitation.

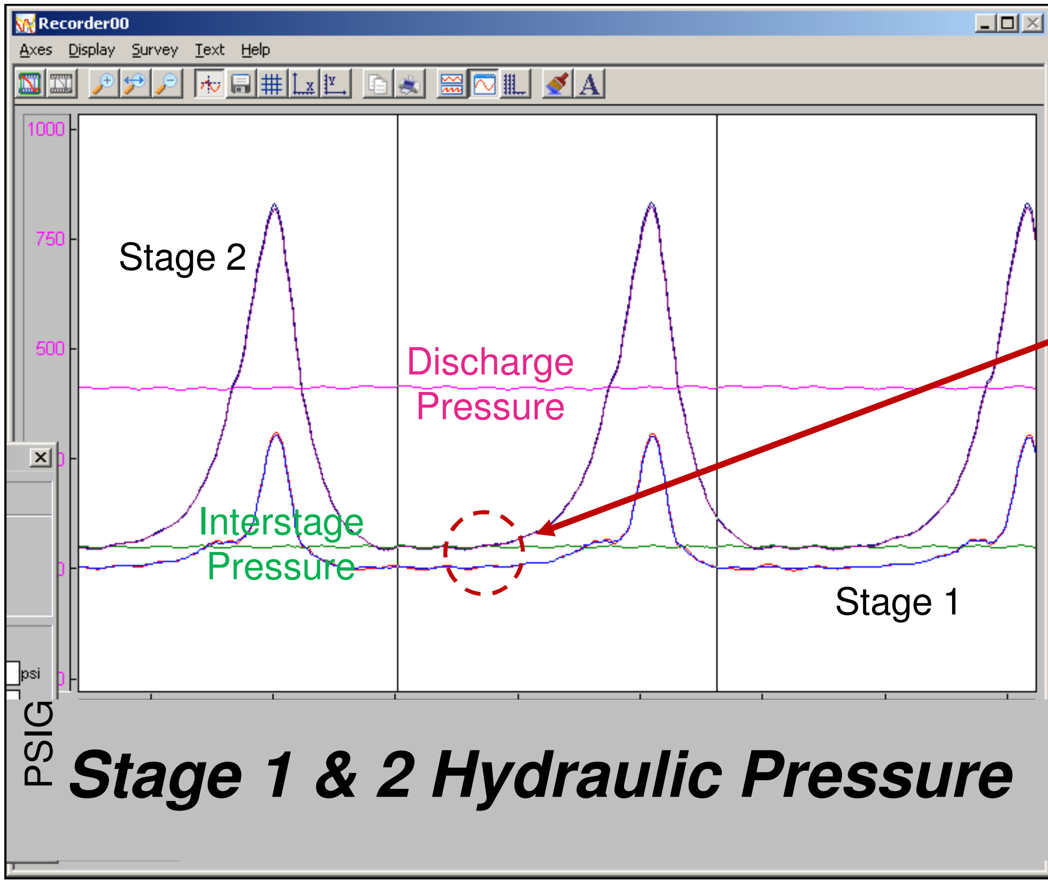


Continued Hydraulic Cavitation

2c. Original Testing @ OEM

Original Equipment
Suction: 10 PSIG
Discharge: 400 PSIG

Increased hydraulic pressure a second time on stage 2 to eliminate hydraulic cavitation.



Hydraulic Cavitation Eliminated

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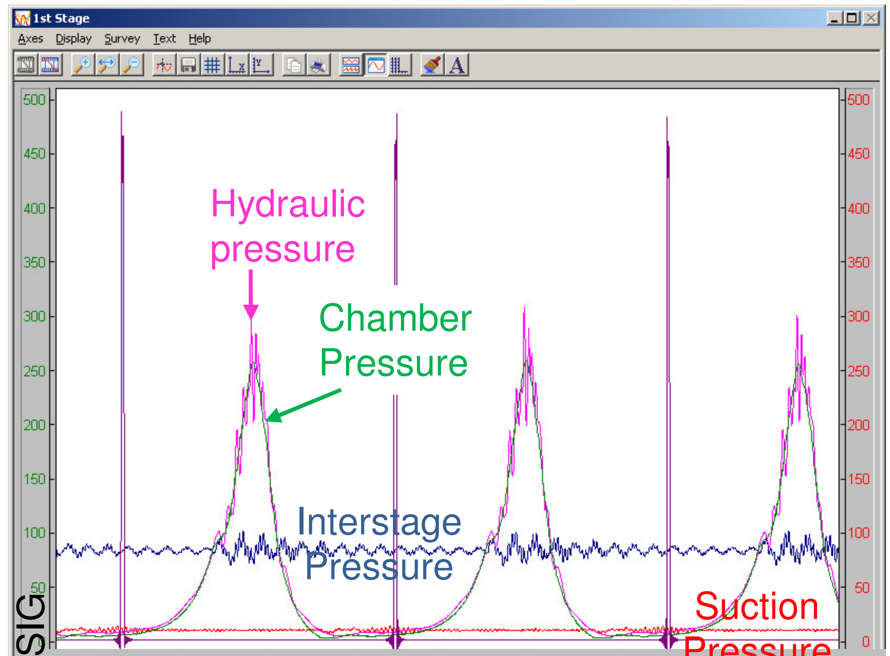
3a. Initial Modifications

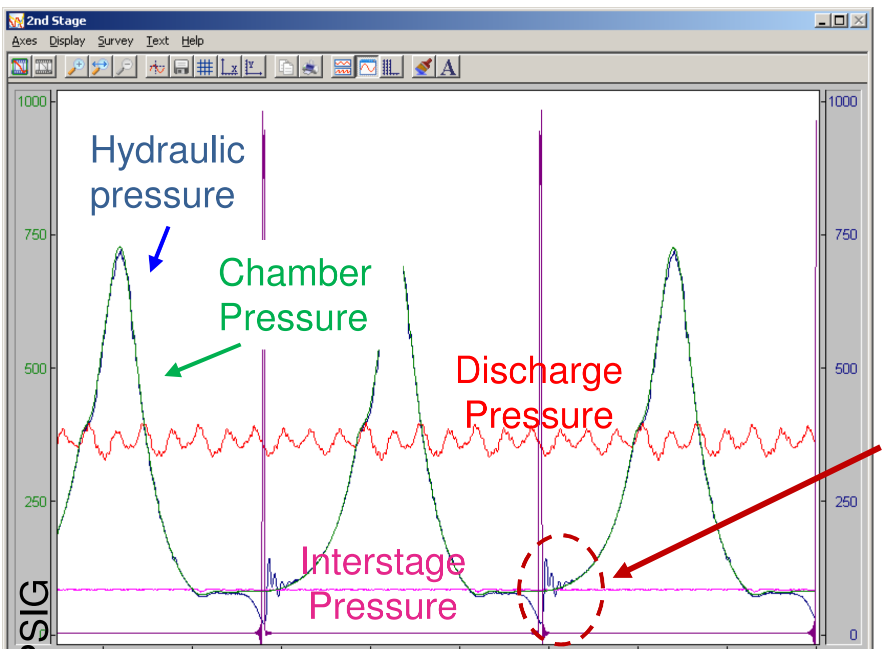
- Modified the shape of the discharge ports from round to kidney shape.
  - Removed metal between every other hole.
  - No capacity improvement measured.
- Changed the type of suction and discharge valves to increase lift.
  - Design evaluated and modified by independent 3rd party.
  - No capacity improvement measured.
- Gas was not restricted in the check valves or in the valve porting.
  - Focused on gas cavity design.
  - ***Modified compressor head to obtain gas cavity pressure measurement.***

3b. Initial Modification Results

Modified Check Valves
Kidney Shaped Porting
Suction: 15 PSIG
Discharge: 400 PSIG



Stage 1 Hydraulic Pressure



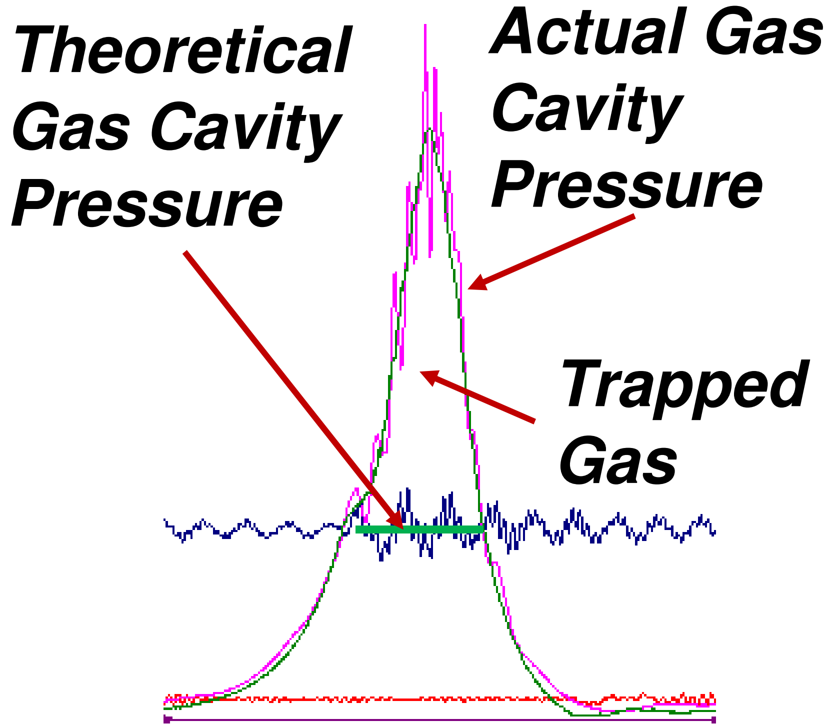
Stage 2 Hydraulic Pressure

Hydraulic Cavitation

Gas cavity pressure and hydraulic pressure do not deviate at discharge pressure!

3c. Initial Modification Results

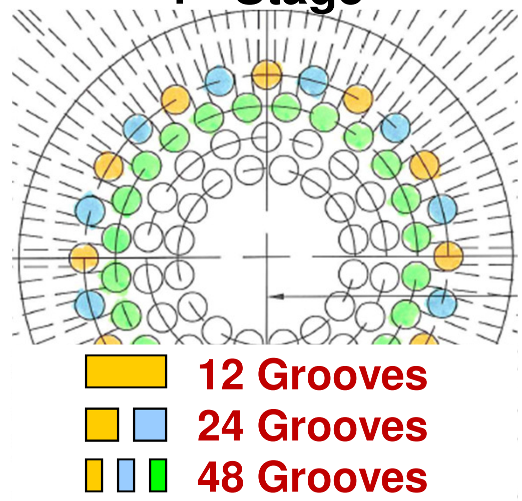
- Gas was not able to exit compressor head.
  - Capacity loss calculated close to quantity of trapped gas.
  - Capacity increased w/ increased hydraulic pressure because more gas was forced from compressor.
  - Compressor is not designed to operate this way!
  - Needed to get the gas to the discharge check valves.
- Time to cut more metal . . .

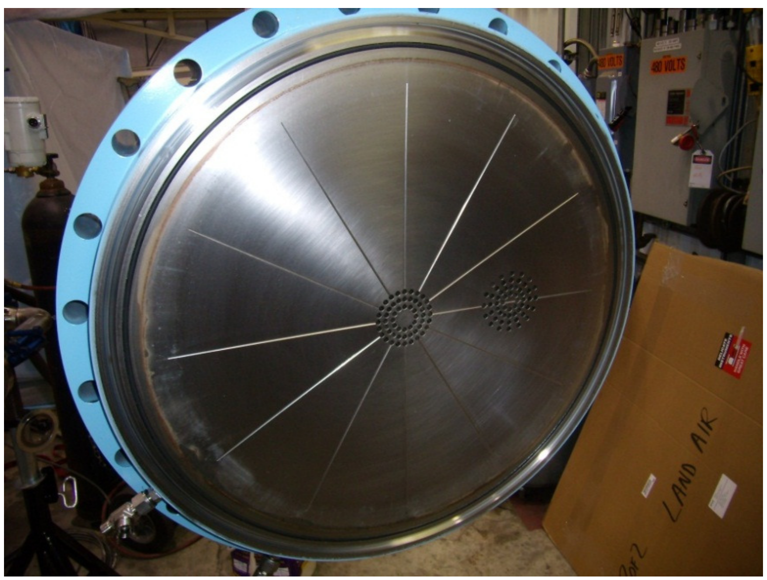


4a. Gas Cavity Modifications

- Step 1: Doubled width and depth on 12 original grooves in the gas cavity.
- Step 2: Doubled the number of grooves (24).
  - 14% stage 1 / 12% stage 2 dead volume increase over original.
- Step 3: Doubled the number of grooves on stage 1 again (48).
  - 34% stage 1 dead volume increase over original.

1st Stage



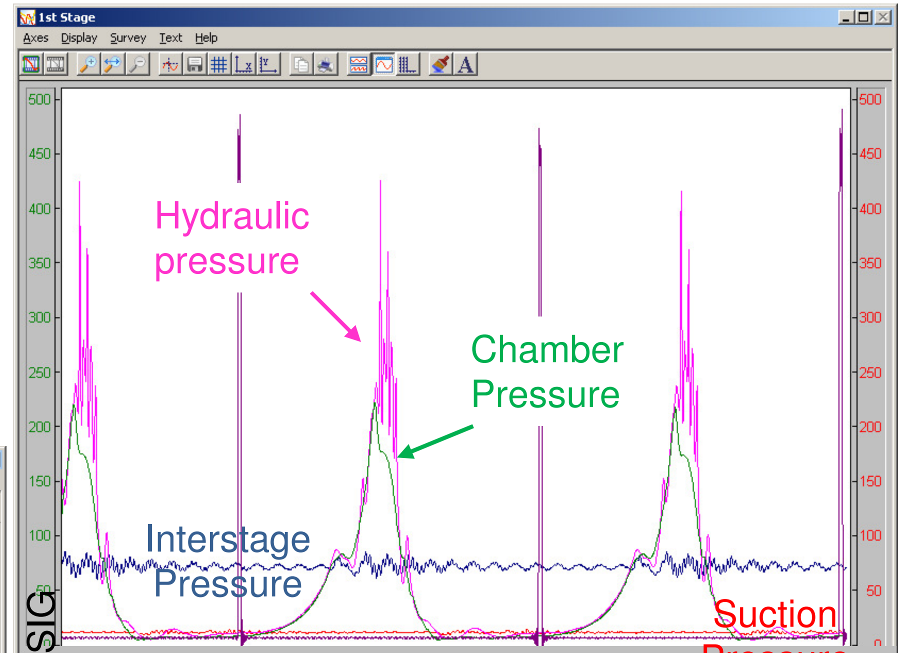


Original 1st Stage

Final 1st Stage

4b. Gas Cavity Modification Results

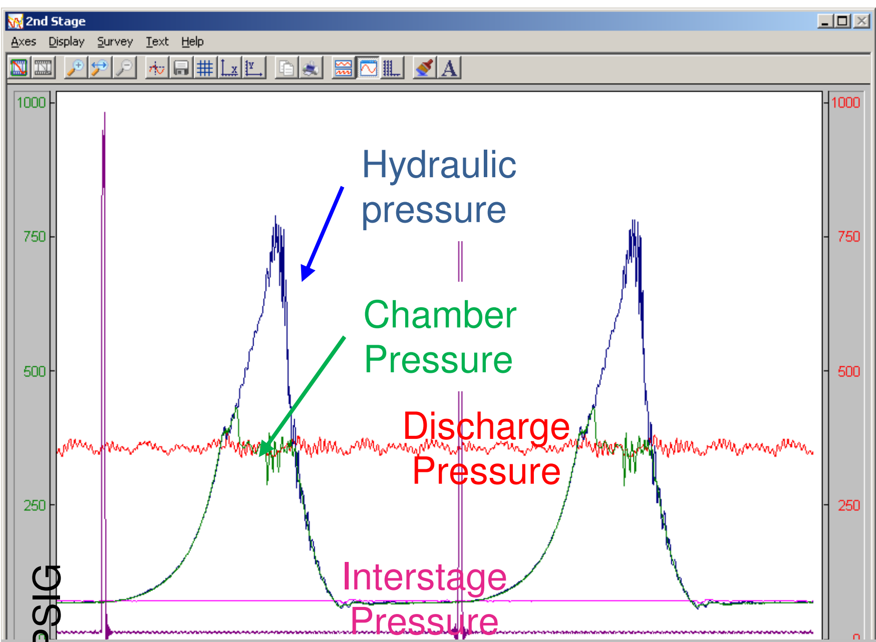
24 Grooves on Stage1
24 Grooves on Stage 2
Suction: 15 PSIG
Discharge: 400 PSIG



Stage 1 Hydraulic Pressure

Significant performance improvement on stage 2.

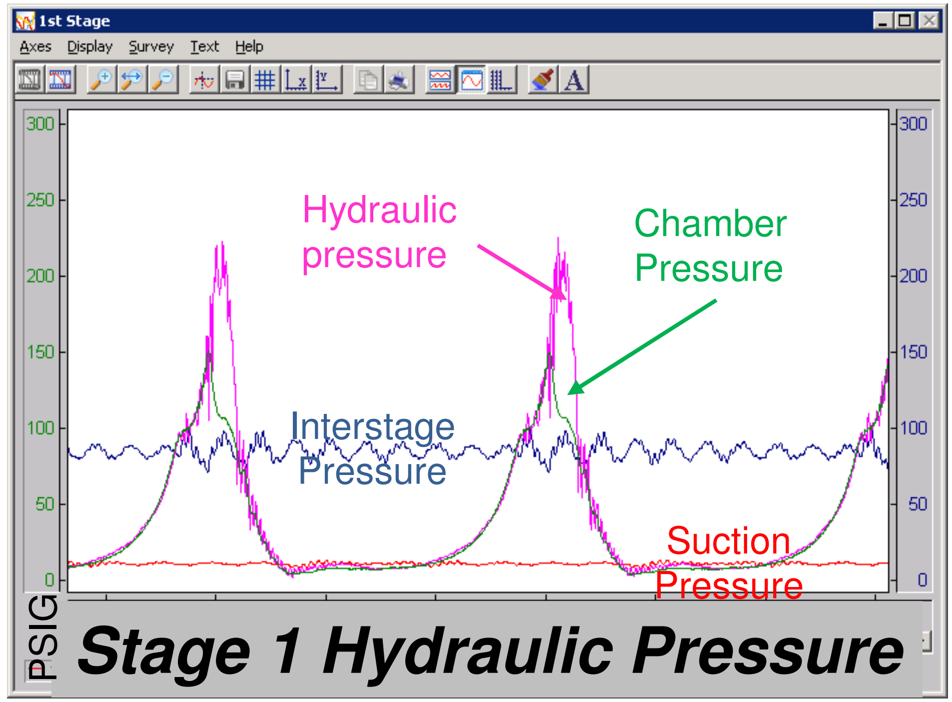
Modest performance improvement on stage 1.



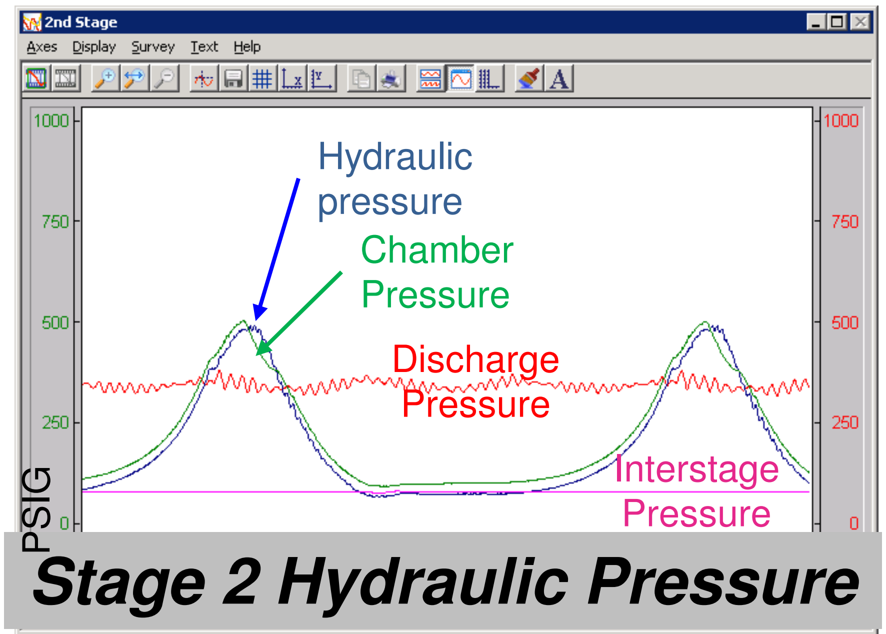
Stage 2 Hydraulic Pressure

4c. Gas Cavity Modification Results

48 Grooves on Stage 1
24 Grooves on Stage 2
Suction: 13 PSIG
Discharge: 380 PSIG



Stage 1 Hydraulic Pressure



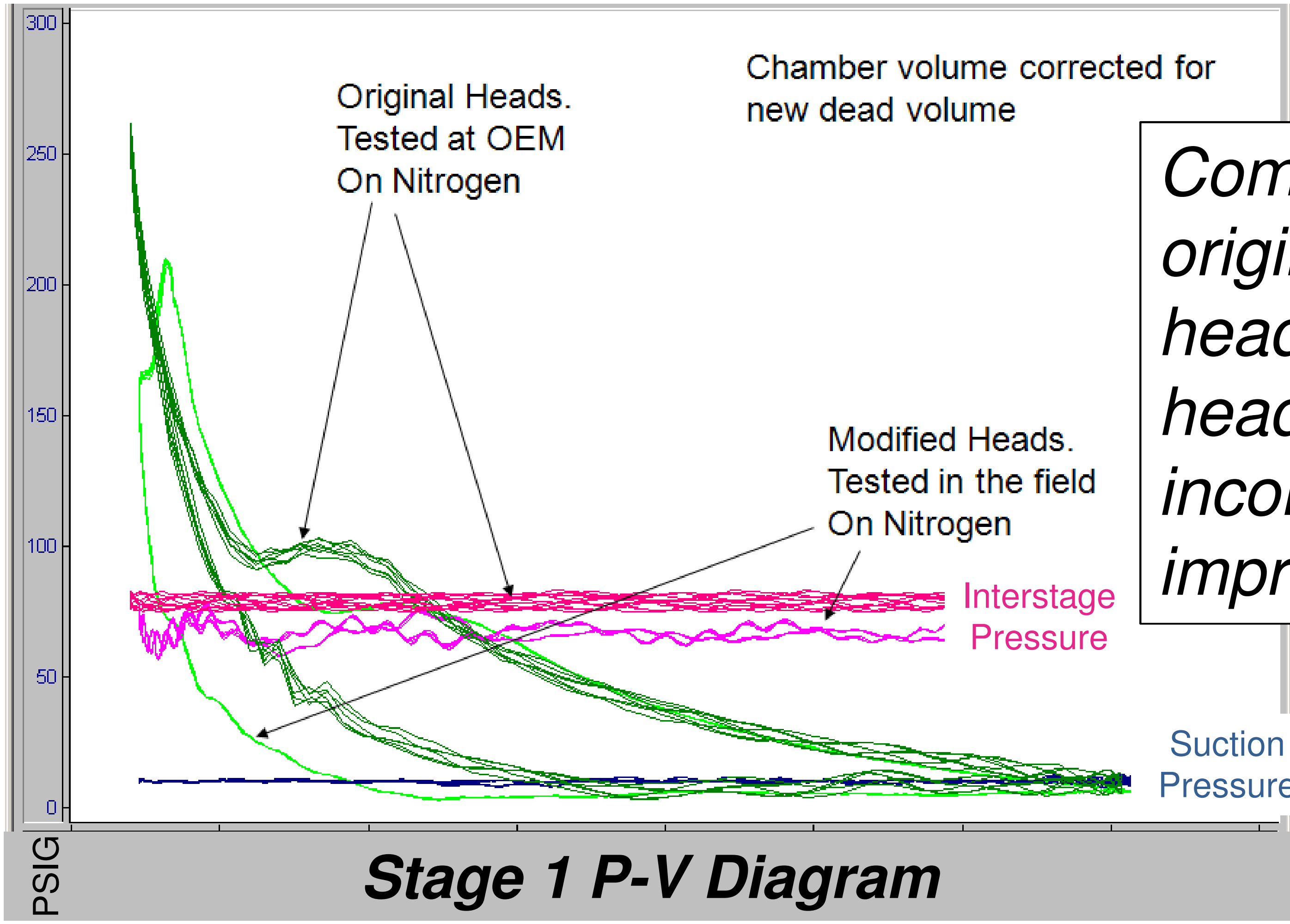
Stage 2 Hydraulic Pressure

Additional improvement on stage 1.

Modest detriment on stage 2 due to increased stage 1 capacity.

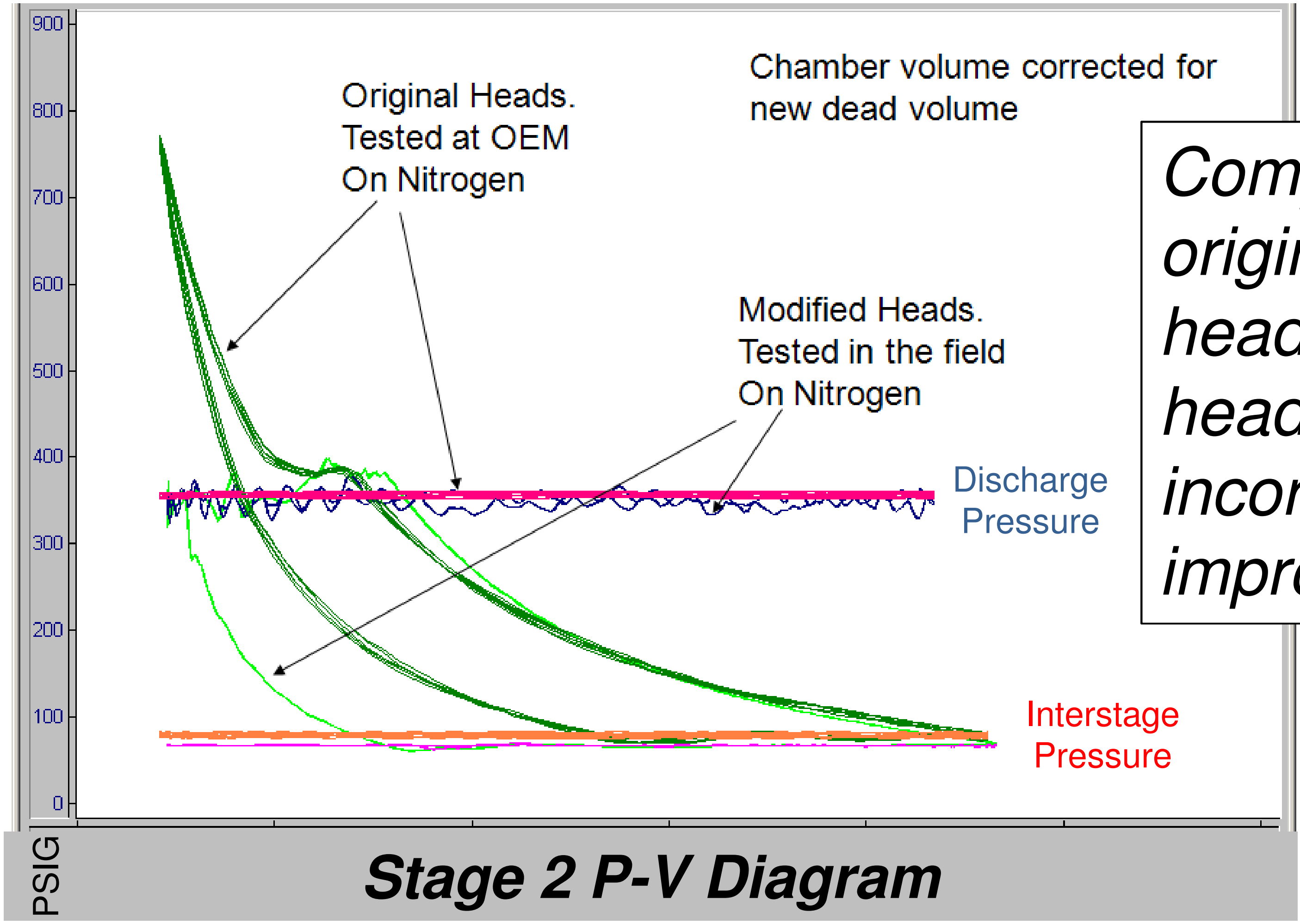
Hydraulic pressure was decreased to lower rod forces.

5a. Summary



Comparison of the original stage 1 heads with the final head design incorporating all improvements.

5b. Summary



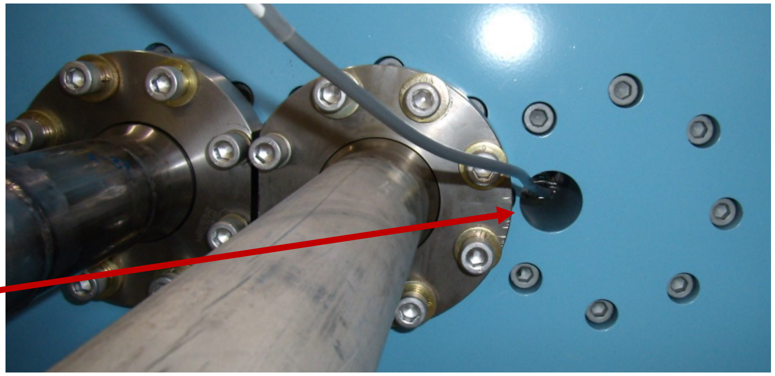
Stage 2 P-V Diagram

Comparison of the original stage 2 heads with the final head design incorporating all improvements.

6. Conclusions

- The root cause of the lack of capacity? The gas cavity profile restricted the ability of the gas to reach the discharge check valve.
  - Modifications to the grooves in the heads improved the ability of the compressor to discharge gas, greatly improving capacity.
  - Increases in the number and size of the grooves resulted in additional dead volume. This increase negatively impacted efficiency.
  - In this case the capacity gains far outweighed the efficiency loss.
  - This would not have worked had the compressor not been “oversized.”
- The most valuable measurement was the gas cavity pressure.
  - Provisions for this measurement are easy to incorporate when specifying and purchasing a new machine.
  - Modifications are more difficult to implement on existing equipment.
- The limiter pressure must be set correctly.
  - Pressure that is too low leads to hydraulic cavitation and poor performance.
  - Pressure that is too high can lead to excessive rod loads.

Gas Cavity Pressure Measurement



THANK YOU!!!

QUESTIONS?